RESEARCH ON FOREST SOILS AND TREE NUTRITION

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Nutrition of Pines

Close attention continues to be given to the two nitrogen fertiliser experiments in middle-aged pine stands growing on wind-blown sand at Culbin Forest (Moray) (*Reports* for 1965 to 1970). The older of these two experiments involved annual applications of ammonium sulphate to Corsican pine over a period of three years, following which the tree crop was sampled for weight determination and chemical analysis. Some 75 sample trees were felled and the opportunity was taken to cut a series of discs from the stems of these in order that examinations could be made of (a) the pattern of change in basal area and height growth that occurred with the onset of deficiency conditions and (b) the pattern of response of stem growth to the fertiliser applications, both at different heights up the tree and between different tree sizes. In order to facilitate measurements of ring widths, radiographs of these discs were prepared, using facilities kindly made available by the Research Division of the Forestry Commission. In addition to this detailed study of past growth, a total enumeration of basal area growth has been made after each growing season, and the height growth that has occurred over recent years has been assessed on trees felled for this purpose in early 1971.

In terms of basal area the trees in this experiment grew very rapidly until the age of 12 years, after which, instead of showing the expected continuing rise, growth per tree became fairly constant. Some years later this was followed by an actual decrease in the rate of basal area growth per tree, a trend that started at age 22 and has continued up to the present (age 42 years). This decrease from age 22 is probably the result of continuing immobilisation of nitrogen in the newly formed humus layer, as has been discussed previously (*Reports* for 1969 and 1970), but the extent of the change in growth pattern at age 12, probably coinciding with canopy closure, was greater than had been anticipated. The pattern of decline in height growth is similar to, although less dramatic than, that for basal area. The addition of nitrogen fertiliser to this crop produced no immediate response, but in the year following first application basal area growth increased several-fold, and continued to increase until 1968, two years after fertiliser application had ceased. In 1969, the heaviest treatments were able to maintain this high rate of growth but by 1970 basal area increment was falling in all treatments. Foliar nitrogen concentrations, on the other hand, started to fall in 1967—that is, immediately fertiliser application ceased. However, by 1970 the concentration of nitrogen in foliage from the heaviest treatment was still as high as 1·75 per cent, more than twice the value of 0·78 per cent for the untreated control trees.

The second pole-stage fertiliser experiment in this forest was designed to compare the response of Scots pine to differing forms of nitrogen fertiliser, these being applied in both 1968 and 1969 at a standard rate of 250 kg nitrogen per ha per annum (*Report* for 1969). In the first year ammonium nitrate produced the greatest increase in foliar nitrogen concentrations, whereas the least increase occurred in those plots given either urea or sodium nitrate, the increase in response to ammonium sulphate occupying an intermediate position. In the second year of application the level of nitrogen in foliage of urea-treated trees was second highest, although still well short of that produced by ammonium nitrate. By the end of 1970, the first year in which no fertilisers were applied, the foliar nitrogen concentrations with respect to fertiliser treatments were approximately 2·2 per cent for ammonium nitrate, 2·1 per cent for ammonium sulphate, 2·0 per cent for urea, 1·8 per cent for sodium nitrate and 1·2 per cent in the untreated control trees. Basal area growth in 1968, the first year of treatment, showed no response, but by 1969 considerable variations appeared that largely paralleled the pattern of foliar nitrogen values found at the end of the previous year. Thus a maximum growth of 1·2 m^2 per ha was stimulated by ammonium nitrate, the untreated control plots producing only 0·7 m^2 per ha.

Nutrition of Sitka Spruce

As described in the previous *Report* a new series of investigations has begun into factors that may control nutrient uptake and diagnostic levels of foliar nutrients in Sitka spruce. Different methods of sampling whole trees of this species have been tested (*Report* for 1969), and following on from this a valid sampling technique has been devised and used in sampling sixteen trees from a 21-year-old stand of this species growing on thin hill peat at a Fetteresso Forest (Kincardineshire).

During the summer months a greenhouse experiment was performed to test the response of Sitka spruce to various forms and rates of introgen supply. As was found in earlier experiments on Corsican pine (*Reports* for 1966 to 1967), Sitka spruce shows a marked preference for ammonium sources of nitrogen. Thus when grown for 204 days at a supply of 3·5 ppm nitrogen (with continuous nutrient renewal and regular adjustment of pH) the weight of plants relative to those grown in ammonium nitrate (taken as 1·0) were 3·0 for ammonium sulphate, 0·9 for calcium nitrate and 1·2 for urea ; similarly at a supply of 28 ppm nitrogen the weights, relative to those in ammonium nitrate, were 1·4 for ammonium sulphate and 0·2 for calcium nitrate ; insufficient plants survived to give an adequate figure for urea. However, variation between plants within treatments was very great and steps are therefore being taken to enable production of clonal material for future experiments.

Effect of Shade on Nutrient Uptake

The short-duration study described in the previous *Report* has continued. Samples of foliage have been taken at monthly intervals over the period November 1969 to December 1970 from five different coniferous species, including Sitka spruce, planted beneath a range of over-cover densities.

Chlorophyll concentrations in these showed a marked variation with time and shade, there being a fairly consistent increase in concentration with decrease in intensity of incident light. Nutrient concentrations are also markedly time-dependent but appear to be less affected by shade. These samples are now being analysed for free amino-nitrogen and soluble sugars.

Nitrogen Mineralisation in Peat and Humus

As the result of preliminary work on this problem (*Reports* for 1969 and 1970) it has been possible to define those factors most likely to be limiting release of nitrogen in available forms from acid peat and mor humus. This, in turn, has enabled the use of more concise experimental approaches, in particular the complementing of investigations of field-treated samples with detailed studies on samples carefully modified under strict laboratory conditions.

Samples of humus were taken in June 1970 from the Scots pine experiment at Culbin Forest (Moray), this experiment having last received fertiliser nitrogen in June 1969. As was found with samples taken prior to the 1969 fertiliser application, the highest concentrations of mineral nitrogen occurred in humus taken from those plots given nitrogen fertiliser, the quantities varying with forms of fertiliser applied and increasing in the order sodium nitrate $<$ urea $<$ ammonium nitrate $<$ ammonium sulphate. Acidity of the humus, measured in a 2·5:1 (v/v) suspension in 1·0 M solution of KCl, also increased in the same order and, with the exception of sodium nitrate, all forms of nitrogen fertiliser depressed the pH of the humus relative to that in samples taken from the untreated control plots. The addition of lime or triple superphosphate, or both, with any of these nitrogen fertilisers tended to both increase the pH of the humus and reduce the proportion of the nitrogen present in mineral form.

Following incubation of these humus samples for nine weeks at 30°C, it was found that the net increase in mineral nitrogen that had occurred was marginally highest in humus samples taken from plots treated with urea, irrespective of whether lime or phosphate had been added. Sodium nitrate, on the other hand, depressed the net production of mineral nitrogen relative to the values found for the control, and the application of either ammonium sulphate or ammonium nitrate appeared to have no significant effect. Recent measurements of the rate of carbon dioxide evolution on incubation suggest that the fertilisers applied to this experiment have altered the rate or pattern of biological activity in the humus, and laboratory experiments are now in progress to establish the extent of these changes and their relation to nitrogen mineralisation.

Samples of peat taken from field plots treated with phosphate and potassium have again shown increased rates of mineral nitrogen production on incubation (*Report* 1970). Laboratory experiments are now under way to investigate more closely this effect of the addition of phosphate and potassium and to determine their optimum concentrations. Samples of peat taken in October 1970 from the drainage experiment at Inchnacardoch Forest (Inverness-shire) were incubated for 120 days at 30°C under both aerobic and anaerobic (waterlogged) conditions. In samples taken from the waterlogged

plot and from the intensively drained plot (water levels in perimeter ditches maintained at depth of 0 and 0·5 m) the highest rates of production of mineral nitrogen occurred under anaerobic conditions, whereas with samples from the less intensively drained plots (water levels in perimeter ditches maintained at depths of 0·1, 0·2 and 0·3 m) this situation was dramatically reversed with highest net production occurring under aerobic conditions. Measurements of carbon dioxide evolution during incubation failed to distinguish between treatments, there being a wide variation in results between samples. A factor contributing to this variation may lie in differences in the quantities of methane produced. Certainly, mass spectrographic analysis of the gases above a sample incubated under anaerobic conditions revealed the presence of greater quantities of methane than of carbon dioxide.